

Effect of Air Pollution on Chronic Respiratory Disease in the New York City Metropolitan Area, 1972

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The effect of air pollution on chronic respiratory diseases (CRD) was examined in a study in the New York metropolitan area in 1972. Four study communities, sites A, B, C and D, were selected for the similarity of socioeconomic and demographic characteristics. Historically, these communities represented an increasing gradient of air pollution levels. However, after air quality improvement in the metropolitan area, Site A had only slightly lower pollution levels than sites B, C and D. In the examination of chronic respiratory symptoms, study hypotheses were established to correspond with historical levels of air pollution. The study population was drawn from parents of children attending elementary school in each site. Information was obtained by means of a questionnaire modified from the 1966 BMRC questionnaire. The analysis was based on 5416 white long-term residents without occupational exposure to irritant dust and fumes. Confounding factors, including smoking status, age, level of education of head-of-household and crowding within the home, were examined. Smoking was found to be the most important factor in determining the level of severity of CRD. The effect of air pollution showed differential patterns among the smokers and nonsmokers. Among the smokers, no air pollution effect was observed. However, among nonsmokers, a statistically significant difference was observed among females. Further, among male nonsmokers a similar pattern was observed, but the effect was not statistically significant. Other possible factors that could contribute to the difference are discussed.

Introduction

Historically, the New York City metropolitan area has experienced high levels of air pollution, consisting of a complex mixture of sulfur and nitrogen oxides, carbon monoxide, hydrocarbons, and particulate matter (1). Elevated levels of these pollutants have been related directly or indirectly to adverse health effects (2-9). However, relatively few studies have been conducted in the New York metropolitan area nor in similarly large urban areas to determine the relationship of exposure to air pollution and the prevalence of chronic respira-

tory disease (9-12). Holland and Stone examined the prevalence of chronic respiratory disease symptoms in populations of Bell Telephone workers in Westchester, New York; Baltimore, Maryland; and Washington, D.C. (10). No significant differences were observed. Five to six years after the initial telephone workers survey, Comstock et al. conducted a repeated survey including all of the old areas as well as several new ones (11). In particular, a downtown Manhattan site was added to the original study of Holland and Stone, thus permitting a suburban, urban contrast to be made between Manhattan and Westchester. Again, no area of residence effect was seen. New York City postal and transit workers were the subjects in a study by Densen et al. (12). The pattern of chronic respiratory disease prevalence of these workers was compared, and after controlling for race, age and smoking, no effect of area of residence was

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observed. In contrast to these studies of occupational groups, Goldberg et al., in a study of parents of school children in the New York City metropolitan area, did find an effect of area of residence: residents of Bronx and Queens, the more polluted areas, had more chronic respiratory disease symptoms than did residents of Riverhead, Long Island (13). The study of Goldberg et al. was carried out in 1970 by the United States Environmental Protection Agency (USEPA) as part of a series of studies under the Community Health and Environmental Surveillance System (CHESS). Two years later, in May 1972, the USEPA carried out another study in the same geographic area with a modified questionnaire. This report evaluates the effect of air pollution on chronic respiratory diseases on the basis of the 1972 study. The study hypothesis is that communities with higher levels of air pollution would show greater prevalence and severity levels of chronic respiratory disease after adjusting for confounding factors. The analysis presented attempts to address the potential sources of problems cautioned by reviewers of earlier CHESS reports (14). In the response to speculations regarding air quality measurements, exposure levels determined from USEPA stations are compared to those from a local air monitoring network. In the analysis of disease symptoms, a multivariate approach is adopted to account for potential confounding factors and an ordinal statistical method is adopted to enhance inferential power.

Materials and Methods

The Setting

The ambient level of sulfur oxides and particulate matter in New York City was high historically, but had dropped drastically since the late 1960's (Fig. 1). The dramatic change during this period could largely be explained by the burning of fuels with lower sulfur content, the improvement of combustion performance for garbage incinerators, the prohibition of open burning, and the control of particulate pollution by major point sources (15).

The present study was carried out at a time when pollution concentrations had already been greatly reduced. The study was designed to test the hypothesis of association of chronic respiratory disease with air pollution levels. Since the disease is chronic in nature, both past and present levels of air pollution are relevant. However, the study was not designed to develop a before and after comparison.

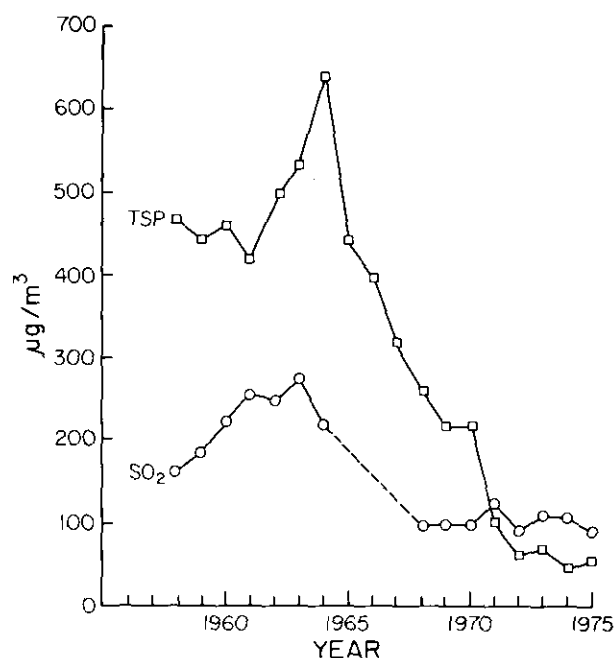


FIGURE 1. Historical trend of (□) total suspended particulates and (○) SO₂, New York City (1958-1975).

The study was carried out in four communities, three of which were chosen for the 1970 study on the basis of prior air quality data to represent a gradient of exposure to sulfur dioxide and total suspended particulate matter. Riverhead, Long Island, was chosen as a low exposure community, the Howard Beach area of Queens as an intermediate exposure community and the Westchester area of Bronx as a high exposure community. Because of the improved air quality at the time of the study, the Queens and Bronx communities had similar pollution concentrations, usually below national primary air quality standards. Historically, however, these two communities have experienced pollution levels well above those experienced by the Riverhead community and well above the air quality standards (1).

The Queens study area was located close to the John F. Kennedy Airport and its residents may have been exposed to organic air pollutants and noise which were not monitored and could not be estimated accurately for previous years. It was, therefore, decided to add an additional community to the 1972 study. This community was to be geographically close to Howard Beach but far enough away from the airport to avoid pollution from that source. The Sheepshead Bay section of Brooklyn, which was about 10 miles southwest of Howard Beach and further from the airport, was selected as the additional community. The relative locations

of the four communities are presented in Figure 2.

In this report, the following designations are used for the four study areas: Riverhead, L. I., site A; Howard Beach, Queens, site B; Westchester, Bronx, site C; Sheepshead Bay, Brooklyn, site D.

Data Collection

Several public elementary schools in each community were selected for similarity of pupil enrollment, socioeconomic status of the families and isolation from major point sources of air pollution. All children in each of the schools were asked to take an explanatory letter and questionnaire home to their parents in May 1972. The questionnaires elicited information about the parents of the children, and the responses to questions concerning these parents formed the data base for this cross-sectional study.

The information on chronic respiratory disease symptoms was ascertained through a series of questions based on the 1966 version of the British Medical Research Council's (BMRC) Chronic Respiratory Disease Questionnaire. In addition to questions about respiratory disease symptoms, information was obtained about family characteristics (race, education of head-of-household, length of residence, living quarter size); and about the individual parents (age, cigarette smoking, exposure to occupational air pollutants). It was requested that the

mother or female guardian of the child fill out the questionnaire whenever possible.

Assessing Air Pollution Exposure

Air monitoring stations were established by the U. S. Environmental Protection Agency in each of the three originally selected communities in 1970. The monitoring sites were located 30-45 ft above the ground on the tops of buildings. At each station, 24-hr integrated samples of sulfur dioxide (SO_2), total suspended particulate matter (TSP), respirable suspended particulate matter (RSP), suspended sulfates (SS) and suspended nitrates (SN) were monitored daily. The level of SO_2 was measured by the West-Gaeke method. TSP was determined from the high volume samplers. The level of RSP was obtained from a cyclone separator. SS and SN were determined as water soluble sulfate and nitrates from a strip of the TSP filter. A full description of the location of monitoring stations and sampling and analysis methodology has been presented elsewhere (1). It was not possible to establish another monitoring station in site D before questionnaire distribution. Since site D (Sheepshead Bay, Brooklyn) was geographically next to site B (Howard Beach, Queens), it was believed that the monitoring results from site B could be used to indicate the approximate pollution exposure for site D residents.

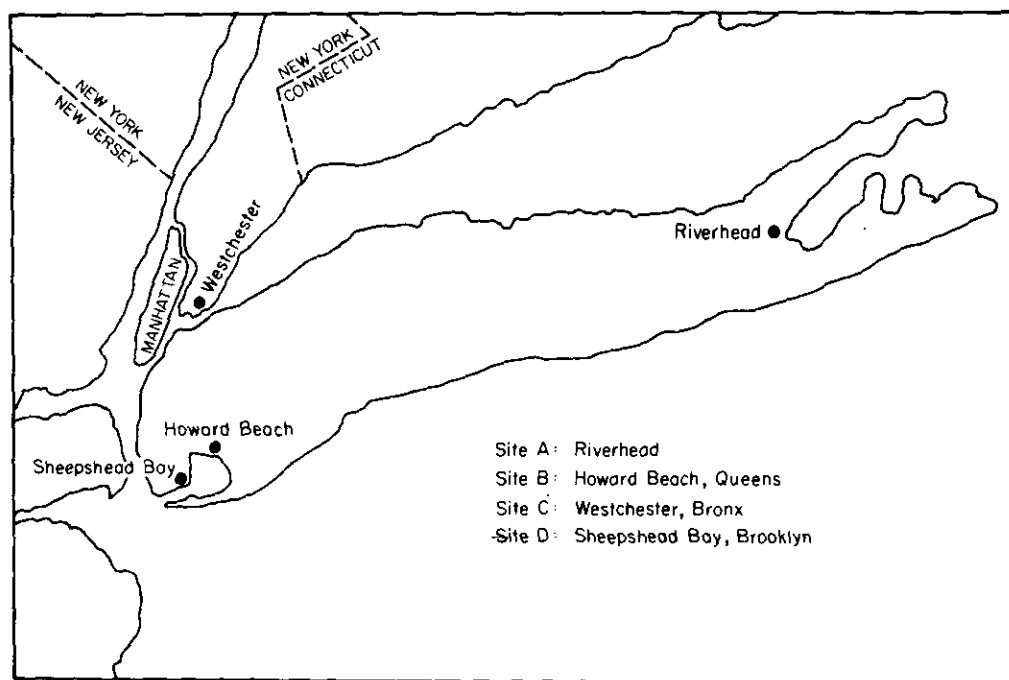


FIGURE 2. Locations of the study communities.

Index of Chronic Respiratory Diseases

Chronic respiratory symptom status was classified on the basis of symptoms reported by the study subjects, into five levels of severity: level I, no symptoms; level II, cough and/or phlegm for less than 3 months per year; level III, cough or phlegm for more than 3 months per year; level IV, cough and phlegm for more than 3 months per year; level V, cough and phlegm accompanied by shortness of breath for more than 3 months per year.

This classification implies an intrinsic order of increasing symptom severity but makes no assumption about the distance between the levels. It is merely a qualitative gradient of the severity level of chronic respiratory disease. Levels IV and V correspond to the epidemiological definition of chronic bronchitis based on the 1966 BMRC questionnaire. Thus, the presence of chronic bronchitis in this study was defined as reporting symptoms Level IV or Level V.

Analytic Methods

Since chronic respiratory disease was classified into five levels of severity based on reported symptoms, it was a response variable measured on an ordered categorical scale. The methodology used for the study of this response variable was the riddit analysis (16). The use of riddit analysis is of particular interest in studying biomedical conditions that lack a clear definition of the presence or the developmental stage of a disease. Chronic respiratory disease exemplifies such a condition. The riddit score of the disease symptom is an indicator of the relative ranking of a person's symptom severity level among the study population.

The use of riddit analysis has been cautioned when an external population is used as the reference group (17). In this analysis, the sex-specific total study population was used as the reference group, and thus it was an internal reference group. Statistical validity of such approach has been demonstrated in the literature (18). A comparison of different approaches in the theory and application of internal versus external riddit scores was discussed elsewhere (19). The extension of the weighted least-squares method for the riddit scores was applied to this study to estimate the mean riddit values for respective subpopulations adjusted for the confounding variables (18, 20). Analysis of variance tables were constructed to test the significance of the main and interaction effects of the independent variables. Statistical models were fitted to the data to allow predictions and estimations of the riddit values for each subgroup. Computations were

done using the statistical package of GENCAT (1976) (21). Significance levels were adjusted for multiple pair-wise comparisons. Since data in the analysis were obtained from parents of families, information on males and females were dependent. Consequently, different models were fitted for each sex-specific population, and no attempt was made to test the significance of the sex effect.

The prevalence of chronic bronchitis was also examined by regrouping the severity levels of chronic respiratory symptoms into a dichotomous variable. Adjusted prevalence rates and odds ratios were calculated by sex and community. Odds ratios were obtained by using the odds of the presence versus the absence of the disease among residents in site A as bases for comparison. Thus, an odds ratio greater than one indicates a relationship consistent with the study hypothesis of an air pollution effect, and an odds ratio less than one implies an effect in a reverse direction from that hypothesized. The small number of persons with chronic bronchitis, as identified by having symptom levels IV and V, in some subpopulations prevented detailed analysis using these terms.

Study Population

The response rates to the questionnaire were similar among the four communities, ranging from 80% in site C to 84% in site D. A total of 4560 questionnaires were returned. Each questionnaire contained information on the parents of the children. Thus, it generally provided data on two adults, except in cases of single-parent families. Study subjects were classified into self-identified racial groups. About 80% of the study subjects were white, 12% black, 2% hispanic, and 5% other racial group. Certain subpopulations were excluded. These included: (1) nonwhite persons; (2) those reporting occupational exposure to irritant dust and fumes (3%); (3) persons who had lived in the community for six years or less (14%). They were excluded because the individuals' air pollution exposure history was not ascertained. The selection of a six year period for the definition of long-term residence was entirely arbitrary. Persons with missing information on essential study variables, such as symptom status of chronic respiratory disease, level of education, length of residence in the community and smoking were also excluded. Among the white population, less than 15% of the males and less than 10% of the females had missing information. Consequently, the analyses of this study were based on the 5416 white long-term residents, of which 2536 were male and 2880 were female (Fig. 3). The larger number of females also reflects

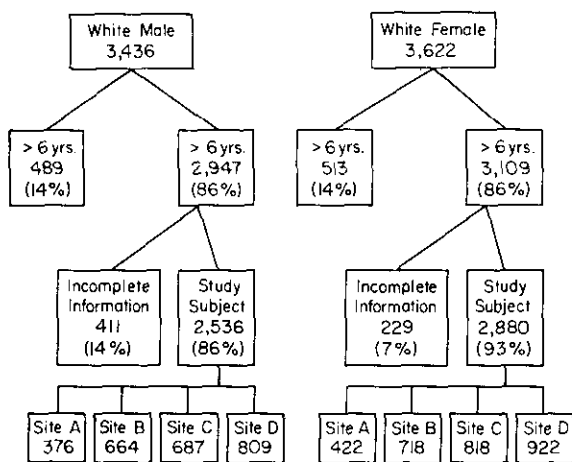


FIGURE 3. Selection process and sample size of the study population.

the fact that most one-parent families had females as the head of household.

Results

Air Pollution Measurements

Air pollution levels based on daily 24-hour integrated measurements are presented in Table 1 in terms of annual mean, 90th percentile and 95th percentile for the years 1971 and 1972. Air quality information for site D was represented by the pollutant concentrations obtained for site B. Geometric means are presented whenever available, because they are less sensitive to acute peak readings.

Site A had lower levels of total suspended particulate matter than site B and site C. The annual geometric mean for site C in 1971 was $78.4 \mu\text{g}/\text{m}^3$ and in 1972 was $78.7 \mu\text{g}/\text{m}^3$, slightly exceeding the national ambient air quality standard ($75 \mu\text{g}/\text{m}^3$), while those at site A and site B were lower than the national standard. The recorded 90th and 95th percentile levels of TSP were also lowest for site A. The annual TSP level of site A was about half of the national standard and even at the 95th percentile did not reach $75 \mu\text{g}/\text{m}^3$. Levels at site B were intermediate to those of sites A and C.

Measurements of respirable particulate pollution were similar among the three communities, but site A had slightly lower levels.

The levels of sulfur dioxide in the study communities were generally low during 1971 and 1972. The annual mean levels were less than half of the $80 \mu\text{g}/\text{m}^3$ permitted by the current national primary air quality standard. A modest gradient for

SO_2 concentrations was found across sites A, B and C.

As expected, measurements of suspended nitrates and suspended sulfates followed the TSP gradient across study sites.

In order to check the reliability of TSP and SO_2 exposure measurements, arithmetic means of 24 hr measurements from the USEPA stations were compared with similar measurements at the local network stations operated by the New York City Department of Air Resources (NYC-DAR) (Table 2). Comparisons were made for the years 1971 to 1974 in sites B and C. Comparable data for site A were not available. Similar techniques for measuring TSP were used by the USEPA stations and the NYC-DAR stations. But, the annual arithmetic means of TSP were consistently lower among the USEPA stations, probably due to loss of particulates during shipment of filters. However, the measurements from USEPA stations were highly correlated with those of the NYC-DAR stations ($r = 0.99$), and both showed that site C had higher exposure levels than site B. The levels of SO_2 were measured through the modified West-Gaeke method by USEPA stations, and through a hydrogen peroxide technique by NYC-DAR stations. The measured levels of SO_2 were very similar between USEPA stations and the NYC-DAR stations. Both also showed higher levels in site C than in site B. Thus, although there existed some discrepancies between measurements obtained from the USEPA and from NYC-DAR stations, the differences were either consistent, in the case of TSP, or small, in the case of SO_2 .

Generally compared to site B and site C, site A had the lowest air pollution levels of TSP, RSP, SO_2 , SN and SS. Although site C usually had slightly higher levels of pollution than site B, this might be related to the fact that the monitoring station for site C was located in a busy commercial area with heavy motor vehicle traffic while the station for site B was located in a low traffic residential area. Thus, particulate pollution would tend to be overstated at site C. Nevertheless, the differences among the three communities were small, and none of them were exposed to heavy amounts of pollution.

Demographic Information

Demographic characteristics of the four communities were obtained from the 1970 U.S. Census (Table 3). Information was gathered for census tracts within a 1.5 mile radius of each of the air monitoring stations, except the center of the circle for site D was the elementary school. Although the study population was not drawn from the census

Table 1. Pollution levels based on daily measurement (in $\mu\text{g}/\text{m}^3$), by type of pollutant and community for calendar years 1971 and 1972.

	1971			1972		
	Geometric mean	90th percentile	95th percentile	Geometric mean	90th percentile	95th percentile
Total suspended particulates, $\mu\text{g}/\text{m}^3$						
Site A	30.8	55.4	64.1	32.1	59.2	70.1
Site B ^a	58.0	101.3	115.5	55.3	91.1	109.0
Site C	78.4	138.6	168.8	78.7	150.4	170.7
Respirable suspended particulates, $\mu\text{g}/\text{m}^3$ ^b						
Site A	28.2	68.3	77.5	21.5	52.6	60.7
Site B	32.6	66.5	72.8	26.4	58.1	70.3
Site C	42.6	76.8	88.5	34.3	72.6	85.4
Suspended nitrates, $\mu\text{g}/\text{m}^3$						
Site A	1.3	3.8	5.0	1.0	3.0	4.1
Site B	2.6	6.8	8.9	1.8	5.2	7.3
Site C	2.9	8.1	11.3	1.9	5.2	6.9
Suspended sulfates, $\mu\text{g}/\text{m}^3$						
Site A	8.5	18.2	22.8	8.4	19.2	22.8
Site B	11.6	21.9	29.2	11.0	21.5	26.6
Site C	12.5	24.7	31.6	11.4	23.3	28.6
Sulfur dioxide, $\mu\text{g}/\text{m}^3$ ^c						
Site A	22.8	53.3	73.5	21.6	54.6	71.8
Site B	34.7	104.3	121.3	37.5	73.8	99.9
Site C	51.4	124.4	154.7	49.5	104.6	147.8

^aSite D is adjacent to site B and is assumed to have essentially the same measured exposures as site B. No direct measurements were obtained for site D.

^bRespirable suspended particulate matter levels in 1971 were based on daily measurements of the last 6 months of the year.

^cArithmetic means are used for sulfur dioxide.

Table 2. Comparisons of monitoring measurements for USEPA stations and NYC-DAR local stations.^a

	Arithmetic mean			
	1971	1972	1973	1974
TSP				
Site B				
USEPA station	83	60	60	57
NYC-DAR station	84	67	59	63
Site C				
USEPA station	87	89	67	68
NYC-DAR station	104	101	69	73
SO ₂				
Site B				
USEPA station	51	38	45	49
NYC-DAR station	64	35	46	35
Site C				
USEPA station	51	50	58	52
NYC-DAR station	59	59	62	35

^aSource for USEPA stations; U.S. Environmental Protection Agency. Measurements for site B are obtained from Station No. 21 in Queens; measurements for site C are obtained from Station No. 31 in Bronx. Source for New York City Department of Air Resources. Measurements for site B are obtained from Station No. 29 in Queens; measurements for site C are obtained from Station No. 38 in Bronx.

tracts and the demographic information so collected did not represent the characteristics of the study population, such information did reflect the general background of the study community.

Information from the census tracts showed that the four communities had similar sex and race

compositions as well as comparable levels of education, but site A had a slightly younger population. In terms of occupation, more than 60% of persons in site B, site C and site D were white collar workers, while only 45% of persons in site A belonged to that category. There were more blue

Table 3. Distribution of demographic characteristics from 1970 census tract information, by community.

	Site A	Site B	Site C	Site D
Sex				
Male, %	47	45	48	46
Female, %	53	55	52	54
Race				
White, %	91	95	99	98
Non-white, %	9	5	1	2
Age				
< 18, %	33	29	28	26
18-49, %	40	44	40	40
50-64, %	17	16	19	21
65 + %	11	11	13	13
Education				
< HS, %	54	48	61	46
HS, %	29	32	28	34
> HS, %	16	20	11	19
Occupation ^a				
White collar, %	45	62	60	74
Blue collar, %	35	27	29	18
Service workers, %	15	10	11	8
Farm workers, %	4	<1	<1	<1
Private household, %	2	<1	<1	<1
Persons below poverty level, % ^b	17	9	9	12

^aOccupations: white collar includes professional, technical, managers, administrators sales, clerical; blue collar includes craftsmen, mechanics, construction operatives, transport, labor; service workers include cleaning, food service, health service, protective service; farm workers include farmers, farm laborers; private household includes private household workers.

^bPoverty level: poverty level income based on a family of four with male head of household = \$3700.

collar workers and service workers in site A than the other communities. Site A also had a higher percentage of persons below the poverty level. These differences may be related to the fact that site A is a small town on Long Island 70 miles east of the New York City area and that the other communities are within the city limits.

Confounding Variables

After limiting the study population to white long-term residents without occupational exposure to irritant dust and fumes, other potential confounding variables including smoking status, age, level of education and crowding of living quarters were considered. The distribution of age was similar among the communities, generally about 50% were between the ages of 30 and 40; and another 30% were between 40 and 50 years of age. This was a relatively young population because the source of the study population was parents of children attending elementary schools. Socioeconomic status, as indicated by the educational level of the head of household, was slightly higher in site D, which had the highest proportion of families having high school or more education. Crowding of living quarters was determined as the number of persons per room in the home. Site A was the least crowded community. The pattern of smoking was very similar

among the communities; about half of the study subjects in each community were current smokers, and about 20% were ex-smokers. Chronic bronchitis rates for ex-smokers resembled those of the nonsmokers. Due to sample size considerations, ex-smokers were grouped with nonsmokers. This pooling would tend to slightly reduce the smoking effect. Males were heavier smokers than females; about 40% of males versus about 25% of females smoked one and one-half packs per day. Smoking intensity was similar among communities. To investigate the relationship among the confounding factors, matrices of rank correlation coefficient (Kendall Tau) were constructed to examine the degree and significance of their associations. It was found that chronic respiratory disease was uncorrelated with age or crowding. The lack of correlation with age was largely due to the homogeneity of age in the study population. There was, however, a small but significant correlation coefficient with the level of education of the head of household. Therefore, the two extraneous factors that were controlled during this analysis were smoking status and level of education of the head of household.

Chronic Respiratory Disease

The prevalence rates of chronic bronchitis, as defined by those reporting the two most severe

symptom levels, are presented for smokers and nonsmokers adjusted for education of head of household (Table 4). As expected, the prevalence of chronic bronchitis was much higher among the smokers than among the nonsmokers. Smoking and education adjusted prevalence rates of chronic bronchitis among the white males ranged from 8.26 to 11.18 per 100 persons, and among the white females ranged from 4.46 to 8.10 per 100 persons.

Sex-specific contingency tables constructed by

the severity of the disease (five levels), education (three categories), smoking (two categories), and community (four categories) (Table 5) had a dimension of $5 \times 3 \times 2 \times 4$. The riddit scores were based on the percentile of the marginal distribution of the five levels of severity when the four communities under study were combined. Because the analysis was based on sex-specific populations, the males and females had different sets of riddit scores, each using their own marginal distribution. By applying

Table 4. Adjusted chronic bronchitis prevalence rates per 100 for white long-term residents, by sex and community.^{a, b}

	Education-adjusted rate		Smoking-education-adjusted rate, overall	Number of observations
	Smoker	Nonsmoker		
Male				
Site A	16.10	2.52	9.12	376
Site B	16.02	6.62	11.18	664
Site C	13.53	3.28	8.26	687
Site D	15.56	4.47	9.86	809
Female				
Site A	8.76	0.38	4.46	422
Site B	13.04	3.42	8.10	718
Site C	9.55	2.60	5.98	818
Site D	10.63	2.18	6.30	922

^aChronic bronchitis is defined as reporting symptom severity level IV or V.

^bDirect adjustment.

Table 5. Chronic respiratory symptom severity levels by education, smoking status and community for white long-term residents.

Community	Smoking	Education	Male					Female				
			I	II	III	IV	V	I	II	III	IV	V
Site A	Smoker	< HS	26	9	14	5	3	32	14	3	7	2
		HS ^a	41	10	20	16	1	51	11	13	3	1
		≥ Col	18	3	10	4	0	29	6	4	4	0
	Nonsmoker	< HS	32	1	2	1	0	47	3	2	0	0
		HS	87	3	6	2	1	120	3	8	1	0
		≥ Col	48	3	9	1	0	52	2	4	0	0
Site B	Smoker	< HS	39	17	23	12	3	44	7	18	10	5
		HS	72	14	35	17	6	102	18	34	15	3
		≥ Col	44	8	10	11	1	62	12	11	10	3
	Nonsmoker	< HS	43	2	1	1	0	72	2	4	0	0
		HS	130	7	19	10	3	135	4	23	3	3
		≥ Col	102	7	14	7	3	98	1	12	5	2
Site C	Smoker	< HS	66	15	21	15	2	87	13	22	9	5
		HS	99	19	34	21	6	128	21	32	16	3
		≥ Col	31	5	15	4	1	47	6	9	5	1
	Nonsmoker	< HS	89	5	5	4	0	123	12	6	1	2
		HS	129	6	17	4	0	165	11	15	3	1
		≥ Col	59	7	5	3	0	63	5	4	2	1
Site D	Smoker	< HS	50	8	17	8	3	58	7	17	2	4
		HS	112	19	37	32	1	163	19	51	26	5
		≥ Col	48	13	20	15	2	63	10	25	12	2
	Nonsmoker	< HS	32	1	5	5	0	56	2	2	0	1
		HS	175	10	28	7	1	205	9	22	2	0
		≥ Col	133	11	13	3	0	137	3	11	4	4
Total		1705	203	383	208	37	2139	201	352	140	48	

^aIncludes completed high school and unfinished college.

the rudit scores thus obtained to the subpopulations, average rudit values were obtained for each smoking and education specific subgroup.

Two phenomena were observed from the raw average rudit scores for the subpopulations, and also from the adjusted average rudit scores shown in Figure 4. Firstly, for both males and females, smokers had higher average rudit values than nonsmokers, indicating the presence of more CRD symptoms in this group. Secondly, among smokers, site A was often not the community with the lowest average rudit values. This was especially true for the males. On the other hand, among nonsmokers, site A was generally the community with the lowest average rudit scores, indicating the existence of an interaction effect between smoking and air pollution. The interaction effect was significant under a trial grand model ($p < 0.10$).

Because of the evidence of interaction, different models were fitted for the average rudit scores of smokers and nonsmokers. Through the applications of weighted least squares method, two models, one for smokers and one for nonsmokers, were fitted for each sex group. Table 6 presents the significance of various effects through the asymptotic chi-square

statistic. The overall smoking effect was obtained from a grand model including both smokers and nonsmokers. As expected, smoking was a highly significant factor in determining the severity level of chronic respiratory disease. Among the smokers (Table 6), the overall community effect was not significant for males or females. Further, none of

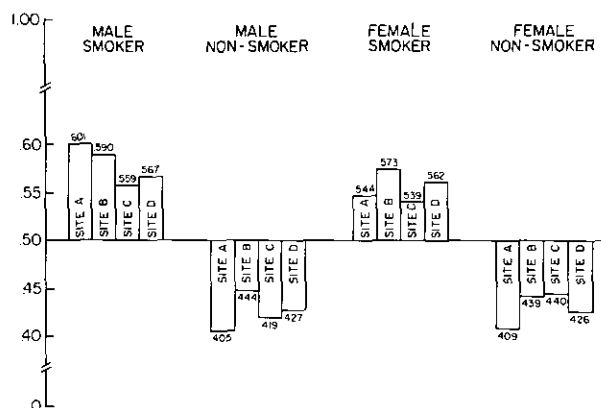


FIGURE 4. Average rudit values for chronic respiratory symptom levels adjusted for education, stratified by sex and smoking status.

Table 6. Analysis of variance table for the testing of effects of average rudit scores.

	Male			Female		
	X ²	df	p	X ²	df	p
Overall smoking effect	276.87	1	<0.01 ^a	240.71	1	<0.01 ^a
Smoker						
Overall community effect	4.45	3	0.22	4.27	3	0.23
Site A vs. (site B, site C and site D)	1.88	1	0.17	0.53	1	0.47
Site A vs. site B	0.21	1	0.65	1.71	1	0.19
Site A vs. site C	3.61	1	0.08	0.06	1	0.81
Site A vs. site D	2.06	1	0.15	0.69	1	0.41
Site B vs. site C	2.29	1	0.13	3.56	1	0.06
Site B vs. site D	1.31	1	0.25	0.41	1	0.52
Site C vs. site D	0.16	1	0.69	1.84	1	0.81
Overall education effect	0.34	2	0.84	0.86	2	0.65
< HS vs. HS ^b	0.04	1	0.84	0.53	1	0.47
< HS vs. Col	0.33	1	0.57	0.78	1	0.38
HS vs. Col	0.19	1	0.66	0.10	1	0.77
Non-smoker						
Overall community effect	5.79	3	0.12	7.91	3	0.05 ^a
Site A vs. (site B, site C and site D)	3.22	1	0.07	6.57	1	0.01 ^a
Site A vs. site B	5.38	1	0.02 ^b	5.55	1	0.02 ^b
Site A vs. site C	0.70	1	0.40	6.23	1	0.01 ^a
Site A vs. site D	1.88	1	0.17	2.12	1	0.15
Site B vs. site C	2.80	1	0.09	0.00	1	0.99
Site B vs. site D	1.35	1	0.25	1.17	1	0.28
Site C vs. site D	0.33	1	0.57	1.37	1	0.24
Overall education effect	2.08	2	0.35	7.18	2	0.03 ^a
< HS vs. HS	1.96	1	0.16	5.51	1	0.02 ^a
< HS vs. Col	1.42	1	0.23	5.44	1	0.02 ^a
HS vs. Col	0.01	1	0.91	0.14	1	0.71

^aSignificant at 0.05 level. Adjustment made for multiple pair-wise comparison.

^bSignificant at 0.10 level. Adjustment made for multiple pair-wise comparison.

the pari-wise comparisons among communities was significant for smokers. On the other hand, among the male nonsmokers, although the overall community effect was also not significant ($p \approx 0.12$), Site A had significantly lower average rids than site B ($p \leq 0.10$). In addition, among female nonsmokers, the overall community effect was significant ($p \leq 0.05$) and site A had significantly lower average rids than site B ($p \leq 0.10$) or site C ($p \leq 0.05$), but not site D. Level of education of the head of household was generally not a significant factor except for female nonsmokers, in which case families with heads of household having less than high school had lower average ridit values than families with heads of household having high school or more education.

Figure 4 demonstrates the expected average ridit values adjusted for level of education. These expected values were obtained from the parameter estimations based on the model fitted. For smokers, the adjusted average ridit scores were generally inconsistent with the study hypothesis. Specifically, for male smokers, site A had higher adjusted average ridit value than the other sites; and for female smokers, site A had higher value than site C. On the other hand, for nonsmokers, the expected average ridit scores in site A were generally the lowest among the study communities, and this difference was consistent among both male and female nonsmokers. But, as indicated in the testing of model parameters, only the difference in the female nonsmokers was statistically significant.

The interaction effect of smoking and site of residence also was observed when examining the relationship between site of residence and chronic bronchitis as a dichotomous variable (Table 7). The odds ratios were less than one among male smokers and above one among male nonsmokers. The

odds ratios for females were noticeably higher among nonsmokers than among smokers. Although none of the odds ratios were significantly different from one and the confidence intervals were wide, the analysis based on odds ratios was internally consistent with that based on average rids.

Discussion

Data analyzed and presented in this report were subjected to a number of procedures designed to improve the quality of results obtained, since criticisms of results of similar earlier studies (1) in a Congressional Investigative Report (14) have cast doubt on the validity of the earlier studies. All original raw data on responses to the chronic respiratory disease questionnaire were carefully edited for data processing errors. To evaluate potential random and systematic errors in air monitoring and chemical analysis, air quality data obtained at study sites by USEPA were compared with data obtained by local agencies. These results revealed good agreement between the USEPA and the local agency for annual SO_2 values and a systematic difference between USEPA and local agency values for particulate pollution, with USEPA values being lower by as much as 25%. However, relative differences in particulate concentrations between study sites remained similar in USEPA and local agency monitoring stations. Lastly, the air quality monitors used for TSP and SO_2 were standard instruments that were widely used throughout the United States. On the other hand, measurements of respirable suspended particulates were obtained from a cyclone separator; the methodology for measuring respirable particulates has yet to be standardized.

Chronic respiratory disease traditionally has been treated as a dichotomous variable. But in this study, use was made of the ordinal nature of the disease, and an analysis was generated that is more effective in detecting a difference when it does exist. The analyses controlled such factors as smoking status and level of education. The data showed that, among the variables examined, smoking was the most important factor in determining the severity level of chronic respiratory diseases.

Generally, the effect of smoking on chronic respiratory diseases overwhelmed the air pollution effect, and the effect of air pollution was small, especially in view of the multiplicity of comparisons that were done. Whether the differences in chronic respiratory disease symptom levels between site A, the low exposure community, and other

Table 7. Chronic bronchitis prevalence: odds ratios between site and 95% confidence intervals for smokers and nonsmokers.^a

	Odds ratio (95% C.I.)	
	Male	Female
Smoker		
Site B/site A	0.99 (0.61-1.64)	1.43 (0.65-2.10)
Site C/site A	0.84 (0.56-1.52)	1.02 (0.56-1.84)
Site D/site A	0.98 (0.61-1.61)	1.18 (0.60-1.92)
Nonsmoker		
Site B/site A	2.79 (0.57-4.16)	6.18 (0.41-12.01)
Site C/site A	1.30 (0.38-3.28)	4.18 (0.33-10.37)
Site D/site A	1.50 (0.43-3.30)	4.14 (0.34-10.24)

^aThe odds ratios are obtained by using the odds of presence versus absence of the disease among residents in site A as the base for comparison. The confidence intervals are based on log odds ratios, and small sample adjustments are used for female nonsmokers.

sites can be attributed to differences in air quality levels is subject to several other considerations. Site A is a suburban small town 70 miles away from the other New York City sites. The residents of site A are engaged in different occupations and related lifestyle activities than residents in other sites. Other factors such as indoor and personal exposure may have a more direct effect on health than community-wide exposure. Most of the questionnaires were filled out by mothers who might misreport information regarding the fathers, especially in items requiring subjective judgement such as occupational exposure and symptom severity levels. By drawing the study population from parents of children attending elementary schools, inference from this study is limited to young adult population, and thus, inherently, inapplicable to the more susceptible populations such as the young children and the elderly. Further, the study was carried out at a time when air quality in the New York metropolitan area was greatly improved. The association of improved air quality and respiratory health status was shown in a series of studies by Ferris et al. on residents of Berlin, New Hampshire (22, 23). Thus, the small differences in respiratory disease prevalence by area in our study could be a result of improved air quality in Bronx and Queens. The 1970 study in the same areas conducted by the USEPA (13) did show a stronger area of residence effect than our 1972 study, supporting the suggestion that improved air quality may have contributed to the small differences shown in our study. However, differences in methodology between the 1970 and 1972 studies may have created the discrepancy. If the effect of improved air quality is being seen, the residual effect of past high levels of air pollution may further diminish with continued improvement in air quality. On the other hand, some persons may have been irreversibly affected by previous high air pollution levels and the entire benefit of improved air quality in this population could already have been obtained by 1972. Thus the observed area differences in respiratory disease may be unrelated to the concurrent area differences in air pollution.

The essential results from our study were similar to those reported by Bouhuys et al. based on a study of residents in Connecticut in 1973 (24). The latter study also showed significantly greater prevalence of chronic respiratory symptoms associated with area differences in pollution levels among nonsmokers but not among smokers; the most pronounced differences were observed among female nonsmokers. Our findings were also in agreement with those found by Kelsey et al. (25), in that among smokers the trend was inconsistent or was

often in the direction opposite to the one hypothesized for an air pollution effect.

In contrast to the 1970 USEPA study, which showed a stronger area of residence effect (13), this study provided evidence suggesting a small air pollution effect only among female nonsmokers. Comparison of the population characteristics of these two studies showed that they were similar in terms of age composition, levels of education, and patterns of smoking. The sex-specific prevalence rates of chronic respiratory disease in the 1972 study were lower than those found in the 1970 study. However, findings from these two studies were not directly comparable. The 1972 study excluded those who lived in the community for six years or less, while this exclusion was not made in the 1970 study. The questionnaire used for the 1972 study was a modified version of that used in the 1970 study. The analytic methods also were different for the two studies. Perhaps the most important difference was that the levels of air pollution in 1972 were lower than those in 1970 as part of a general reducing trend. Whether this reduction of air pollution levels contributed to the disappearing air pollution effects was a hypothesis untested due to the study design.

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